“Methods of Cutting” Ecological Inventory Draft Report

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Photo 1. “Methods of Cutting” mixed conifer stand (plot no. 2) in the Sierra National Forest.

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Summary

We examined historic (1911 to 1929) and current (2013) stand inventory data for three 10-acre (4 ha) plots located in two mixed conifer and one ponderosa pine (*Pinus ponderosa*) stand of the Bass Lake Ranger District in the Sierra National Forest. We provide a summary of the stand variables in these historic plots and compare this information to current inventory data in both mixed conifer stands and Forest Inventory and Analysis (FIA) data for the southern Sierra Nevada. Current stand inventory of the ponderosa pine stand was precluded due to past logging and severe burning, therefore, comparisons in this stand was limited to historic and current FIA inventory data. Compared to current conditions, historic (1929) or presettlement (1860) stands were generally characterized by: (1) lower tree density especially in the smallest size class, (2) decreased basal area, (3) greater average tree diameter, (4) more even (i.e., uniform) tree size class distributions, (5) reduced canopy cover, (6) higher density of shade-intolerant Jeffrey pine (*P. jeffreyi*) and lower density of shade-tolerant white fir (*Abies concolor*), (7) lower snag density, (8) decreased tree regeneration of shade-tolerant red fir and incense cedar, and (9) greater shrub cover. Our results have several important implications for the management and restoration of mixed-conifer and ponderosa pine forests in the Sierra National Forest.

Background

In the early 20th century, three unlogged 10-acre forest plots located in mixed conifer (2 plots) and ponderosa pine (1 plot) stands were surveyed and mapped in the Sierra National Forest by Duncan Dunning, a silviculturist with the U.S. Forest Service Research Branch (Dunning 1926, Bachman 1931). Dunning and his staff inventoried and mapped all live and dead trees within each plot, providing a rich data set for established historic reference conditions within these stands. Their initial surveys for each plot occurred in 1911 (plot 1), and 1929 (plots 2 and 3) prior to forest management treatment. The mixed conifer stands were selectively logged in 1929, primarily involving the removal of 40 to 50% of the largest ponderosa or Jeffrey pines (>30 inches dbh), and stands were not harvested or burned since that time. The ponderosa pine stand (plot 1) was harvested in 1906, primarily involving the removal of the dominant ponderosa pine trees in the stand. This stand experienced substantial harvest and a severe wildfire in the decades following the initial harvest. Consequently, current stand inventory data was limited to the mixed conifer plots that lacked recent human-induced change.

In 2013, we resurveyed the two mixed conifer plots to evaluate changes in stand structure between historic (1929) and current (2013) periods. When possible, we also approximated the presettlement (1860) stand conditions to determine whether current conditions were potentially within the natural range of variation (NRV) for these forest types. Our specific objectives included:

- Quantify historic (1911-1929) and estimate presettlement (1860) stand structural patterns in mixed conifer and ponderosa pine stands in the “Methods of Cutting” (MOC) study plots on the Sierra National Forest to quantify the reference conditions for these forest types within the study area.

- Compare historic or presettlement reference with current conditions in these stands and evaluate potential departure from NRV for the following stand variables: tree density, tree size class distribution, basal area, canopy cover, tree species composition, snag density, tree regeneration, and shrub cover.
- When possible, further compare the MOC historic and current conditions with current ecoregional stand estimates derived from FIA plots in the same forest types from the southern Sierra Nevada.

Photo 2. Current dense and closed canopy stand conditions in "Methods of Cutting" mixed conifer stand (plot no. 3)

Methods

Study site

All study sites were located on the Bass Lake Ranger District of the Sierra National Forest (Fig. 1). Plots no. 2 and 3 were located at approximately 6670 ft. (~2030 m) elevation in a late-seral mixed-conifer forest with many large (>30 inch dbh) and old (>150 year) trees. Plots were situated on gentle 8 to 12 degree slopes with a north, south, or west-facing aspect. During historic and current periods, plots were dominated by white fir and sugar pine (*P. lambertiana*), but significant elements of red fir (*A. magnifica*), incense cedar (*C. decurrens*), and Jeffrey pine. There were infrequent occurrences of black oak (*Quercus kelloggii*) and canyon live oak (*Q. chrysolepis*) within these stands, but neither oak species was recorded in the historic stand inventories. Current understory vegetation cover was sparse and patchy (average cover = 4%) and dominated by mountain whitethorn (*Ceanothus cordulatus*), bitter cherry (*Prunus emarginata*), chinquapin (*Chrysolepis sempervirens*), and Sierra gooseberry (*Ribes roezlii*). Herbaceous plant cover was also sparse and dominated by shade-tolerant species such as *Symphoricarpos mollis*, *Corallorhiza maculata*, *Pteridium aquilinum*, *Pyrola picta*, *Phacelia hydrophylloides*, *Viola lobata*, and several graminoids. In 1929, trees were harvested from this plot using either a group selection (plot 2) or selective marking system (plot 3) that targeted the largest (>35 inch dbh) yellow pine trees as well as a smaller proportion of large sugar pine, white fir, and red fir trees. No incense cedar trees were harvested in these early operations, and no further tree harvest followed these historic "Methods of Cutting" treatment plots.

Plot no. 1 was located at approximately 4500 ft. (~1370 m) elevation in a ponderosa pine stand that was considered late-seral prior to mechanical harvest in 1906. This plot is located on low to

moderate slopes with east and west-facing aspects. The stand is dominated by ponderosa pine, but also contained sugar pine, white fir, incense cedar, black oak, and canyon live oak. The understory was dominated by mountain misery (*Chamaebatia foliolosa*) but also included whiteleaf manzanita (*Arctostaphylos viscida*), deer brush (*Ceanothus integerrimus*), mountain whitethorn, and Sierra gooseberry. Trees in this stand were harvested using a group selection method targeting the largest (>35 inch dbh) ponderosa pine, sugar pine, and white fir trees, with a relatively smaller proportion of large incense cedar removed. The initial harvest of plot 1 in 1906 was followed by extensive mechanical treatments and wildfire in the subsequent decades.

Field Methods and Data Analysis

In June 2013, we inventoried a total of 0.3 ha (0.741 acre; ~7.4% of total plot area) within each 10-acre mixed conifer plot (i.e., plots 2 and 3; hereafter referred to as "mixed conifer plots"). We used six 0.05-ha (0.124 acre; 12.6-m radius) inventory plots based on an approximate 200-ft (~60 m) grid established from the 1929 plot map. Plot 1 (ponderosa pine stand; hereafter "ponderosa pine plot") was not inventoried for reasons stated above. Recorded variables included:

- Site attributes (e.g., slope, aspect, GPS coordinates),
- Stand attributes (e.g., density of live and dead trees, live and dead basal area, snag density),
- Tree information (e.g., dbh, species, status, and historic tag number),
- Vegetation and understory cover (e.g., overstory canopy cover, shrub cover),
- Tree regeneration (density and species of seedlings and saplings).

Photo 3. Historic open stand conditions in a mixed conifer stand in the vicinity of the 1929 Dunning stand inventory.

We analyzed conditions based on the original Dunning inventory data for the ponderosa pine plot (1911) and mixed conifer plots (1929), which hereafter are referred to as 'historic' conditions. Dunning (1926) noted that historic conditions for plot 1 were "*only approximate since "remaining" trees were not measured until 4 years after cutting, and cut tree measurements were obtained by stump tally in 1917*." We also approximated the presettlement (1860) conditions in mixed conifer and ponderosa pine stands by estimating the overall density of trees in the smallest size class (4 to 11 inch dbh) to better reflect presettlement patterns of mixed conifer and yellow pine stands based on North et al. (2009), North (2012), and Safford (2013); all other size class densities were unchanged for the presettlement estimation. Presettlement small tree (4 to 11 inch dbh) density was calculated as the average of all larger size classes in the stand, reflecting the relatively flat distribution of size classes in presettlement mixed conifer and yellow pine stands (presettlement estimate was ~20% of historic value). We also compared historic MOC plot data with current USFS Forest Inventory and Analysis (FIA) data summaries (summarized in 2013) that represent a current estimate of ecoregional-scale variation in stand variables for mixed conifer and yellow pine forests. These FIA summaries were based on a total of 291 plots in mixed-conifer and 136 plots in yellow pine (ponderosa pine and Jeffrey pine) forests, collected between 2001 and 2008 for the west slope of the southern Sierra Nevada (including Sierra and Sequoia national forests). FIA summaries predominantly represent secondary-growth stand conditions within the southern Sierra Nevada.

We used a correction factor for estimating current tree densities in mixed conifer plots, since: (1) our 7.4% area sample did not adequately cover the full range of stand variation, and (2) these plots avoided areas impacted by larger, historic skid trails that were often higher in current small tree density relative to neighboring areas. This correction factor was a conservative estimate of tree densities that likely underestimated actual tree densities, but it nevertheless provided a more accurate representation of existing densities and stand conditions than uncorrected plot values. We calculated current tree density within mixed conifer stands as:

$$D = \frac{\mathrm{C}}{\mathrm{M/I}}$$

where *D* is the corrected tree density, *C* is the current density estimated from 2013 stand inventory (i.e., uncorrected plot values), *M* is density based on historic stem maps (focusing exclusively on approximate location of current survey plots), and *I* is the density from historic stand inventory summaries for an entire 10-acre plot. This correction factor (*M*/*I*) varied between 1.6 (plot 2) and 2.1 (plot 3) for mixed conifer stands.

We estimated canopy cover in the field for current inventories using ocular methods. We also estimated canopy cover using Forest Vegetation Simulator (FVS) modeled values (Dixon 2010) based on historic and current stand inventory data. We estimated historic shrub cover by measuring their cumulative coverage on historic stand maps of both mixed conifer stands.

We did not conduct formal statistical tests on our data due to the relatively small sample size of MOC plots (i.e., N = 2 for mixed conifer and N = 1 for the ponderosa pine). However, when

possible we calculated error bars (standard deviation; SD) to provide some means for comparison between time periods and data sources. Therefore, comparisons between historic and current MOC plots should be interpreted with caution.

Photo 4. Historic open stand conditions in a ponderosa pine stand on the Bass Lake Ranger District, Sierra National Forest.

Results

Mixed Conifer Stands (Plots 2 & 3)

Tree density averaged 2.3 to 3.4 times greater in current MOC and FIA plots compared to presettlement MOC mixed conifer plots (Fig. 2). Average tree basal area increased 44% during the same period (Fig. 3). Tree densities in the smallest size class increased substantially from historic to current periods, and current FIA plots in the southern Sierra Nevada had the lowest density of trees in the largest size classes (≥30 inch dbh; Fig.4). Overall, stand composition was similar between historic and current periods, although there was a trend of decreasing density of Jeffrey pine and increasing density of smaller-diameter white fir and red fir over time (Fig. 5, 6; Appendix A, Fig. 17). Average tree diameter was greater in presettlement than current MOC mixed conifer stands (Fig. 7). Consistent with the pattern of increasing tree density over time, canopy cover in historic MOC plots was lower than current MOC plots (based on FVS-modeled or ocular field estimates; Fig. 8). Canopy cover estimates from current FIA plots overlapped with both historic and current MOC values. Snag densities were notably lower in historic than current MOC plots, although current FIA values overlapped with both of these periods (Fig. 9). Tree regeneration was slightly greater in current than historic MOC plots, although there was high overlap between historic MOC, current MOC, and FIA plots (Fig. 10). Increased

regeneration in MOC plots was attributed to red fir and incense cedar, with a notable deficiency of detectable Jeffrey pine and sugar pine regeneration in both periods (Fig. 11). Shrub cover was 4.2 times greater in historic compared to current MOC plots (Fig. 12). Many of these changes in stand structure were evident from historic and current photo comparisons taken in MOC plot 2 (Appendix B, Fig. 20–23).

Ponderosa Pine Stand (Plot 1)

Tree density was 4.9 times greater in current FIA plots located in yellow pine forests than the historic MOC ponderosa pine stand (Fig. 13). In contrast, basal area was similar between FIA and the historic MOC ponderosa pine plot (Fig. 14). Canopy cover in the historic ponderosa pine MOC plot was similar to NRV estimates from Safford (2013), but both of these reference estimates were lower than current FIA values for yellow pine stands in the southern Sierra Nevada (Fig. 15). Shrub cover (primarily mountain misery) averaged approximately 16% in the historic MOC ponderosa pine stand, but shrub cover was highly variable and nearly 2 times greater in current FIA stands (Fig. 16). Size class distribution of estimated presettlement (1860), historic (1911), and current (2002-2008) FIA plots illustrates the trend of increasing tree densities in the smallest size classes (<17 inch dbh) over time (Appendix A, Fig. 18, 19).

Conclusions

Our results with the historic MOC plots are consistent with previous work demonstrating that, compared to current stand conditions, presettlement (1860) and historic (early 20th century) mixed conifer and yellow pine stands were generally characterized by: (1) lower tree densities, (2) greater evenness in size class distribution with relatively fewer trees in the smallest size classes and more trees in the largest size class, (3) larger mean tree diameter, (4) greater density of shade-intolerant tree species (i.e., Jeffrey pine, ponderosa pine) and lower density of shade-intolerant species (especially white fir), (5) reduced canopy cover, (6) lower snag densities, (7) lower tree regeneration densities especially for shade-tolerant red fir and incense cedar, and (8) greater shrub cover especially compared to contemporary closed-canopy stands (see North et al. 2009, North 2012, and Safford 2013). Several of these patterns were apparent despite our more conservative approach in estimating tree densities and basal area within historic stands (see Methods section).

Forest restoration projects in the Sierra National Forest may want to consider the following MOC presettlement or historic reference conditions when developing desired conditions for mixed-conifer (MC) or ponderosa pine (PP) forests:

- Tree densities (≥4 inch dbh) were approximately 45 to 50 trees per acre (MC) or 35 trees/acre (PP);
- Historic basal area was 150 to 200 ft^2/acre (MC) or approximately130 ft^2/acre (PP);
- Tree size class distribution was relatively flat, with fewer trees in the smallest size classes (<17 inch dbh) and more trees in the largest size classes (≥30 inch dbh) than current conditions (MC and PP);
- Density of ponderosa pine and Jeffrey pine was greater in historic than current stands, with nearly 2 large (≥24 inch dbh) Jeffrey pine trees per acre in historic MC stands;

- Historic canopy cover typically averaged 35 to 45% (MC) and 18 to 23% (PP);
- Current snag densities were more than seven times greater than under historic conditions in MC stands (approximately 3 snags per acre);
- Tree regeneration had a higher proportion of shade-intolerant species than present;
- Historic shrub cover averaged between 14 and 18% (MC and PP).

We emphasize that these stand features were highly variable within mixed conifer and ponderosa pine stands of the Sierra Nevada, and average stand conditions were rare in these active-fire forests (North et al. 2009, North 2012, Safford 2013). For example, historic stem maps and photos (Appendix B, Fig. 20–23) for all three 10-acre MOC plots indicate a high degree of spatial variation in stand conditions (e.g., tree density, canopy cover, shrub cover). Consequently, we recommend varying these stand features with changes in topography and site productivity, and using stand averages only as a general guide for forest restoration. For further information on tree spatial patterns and canopy gaps in mixed conifer and yellow pine forests, we recommend consulting the following sources in addition to those provided above: Lydersen et al. (2013), Lydersen and North (2012), and Churchill et al. (2013).

Acknowledgements

We thank Lisa Zander and Stephanie Eyes for their invaluable assistance in field data collection. Eric Knapp kindly provided historic MOC plot photos, stand maps, and reports. We also thank the USFS Region 5 Remote Sensing Lab for providing FIA data summaries.

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Figures

Figure 1. Map of the historic “Methods of Cutting” stand inventory plots on the Bass Lake Ranger District of the Sierra National Forest. Plot locations include one 10-acre ponderosa pine plot (Plot 1) and two 10-acre mixed conifer plots (plots 2 and 3). Sierra National Forest boundary is outlined in red.

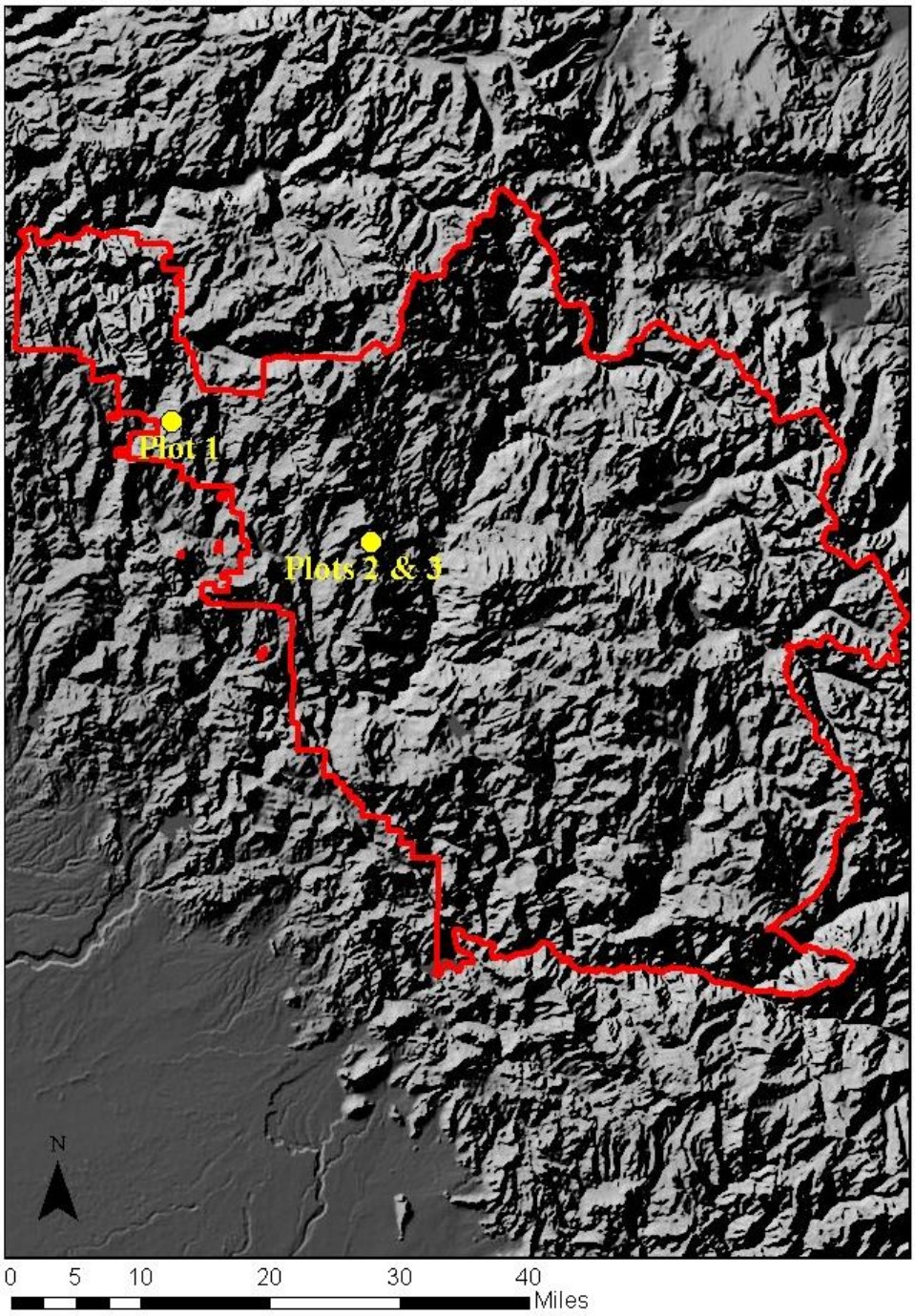


Figure 2. Mean (± SD) tree density for presettlement (1860) and current re-inventory (2013) "Methods of Cutting" (MOC) plots, and current FIA (2013) plots in mixed conifer stands. FIA data in this and following figures for mixed-conifer forest is based on a summary of 291 plots exclusively from the southern Sierra Nevada (including the Sierra and Sequoia national forests).

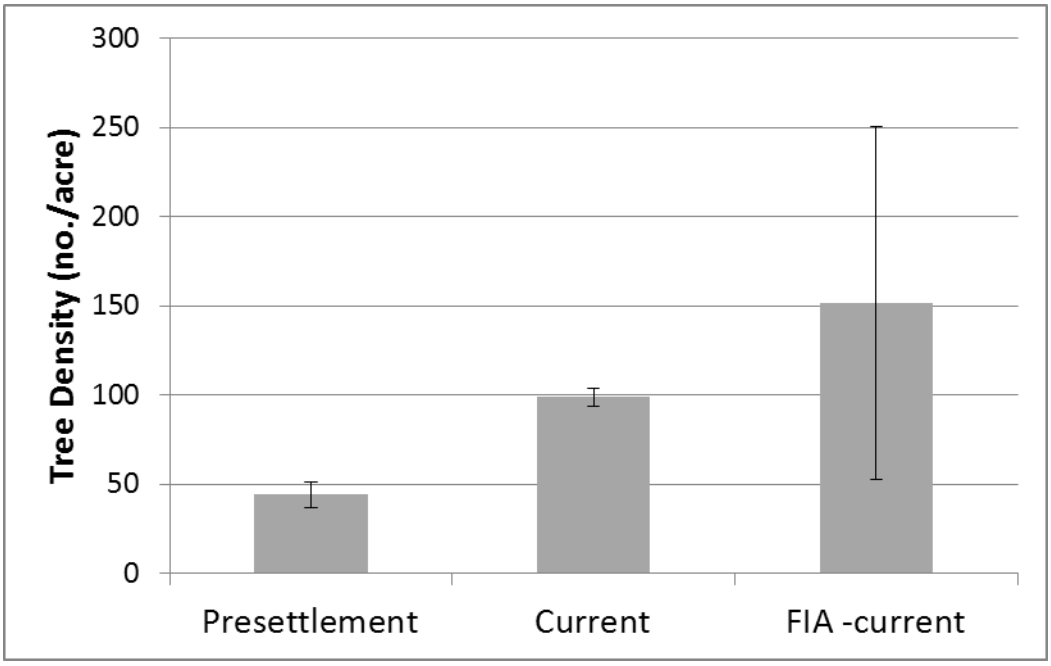


Figure 3. Mean (± SD) basal area for presettlement (1860), current re-inventory (2013), and current FIA (2013) mixed conifer stands.

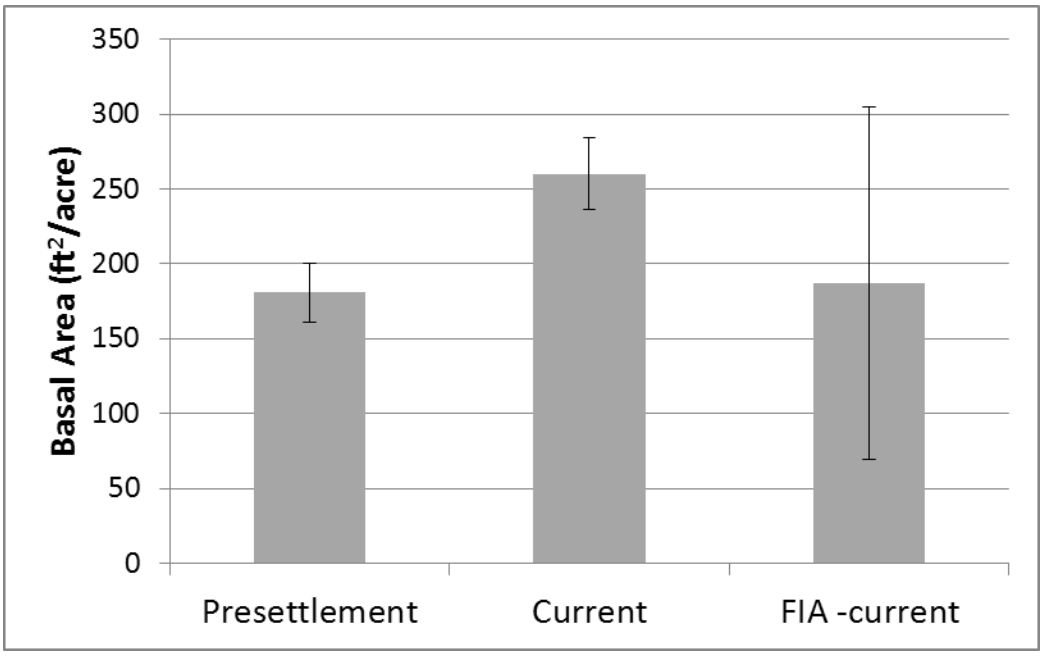


Figure 4. Size class distribution of presettlement (1860), current re-inventory (2013), and current FIA (2013) mixed conifer stands. Diameter class bins for FIA data are based on approximate values.

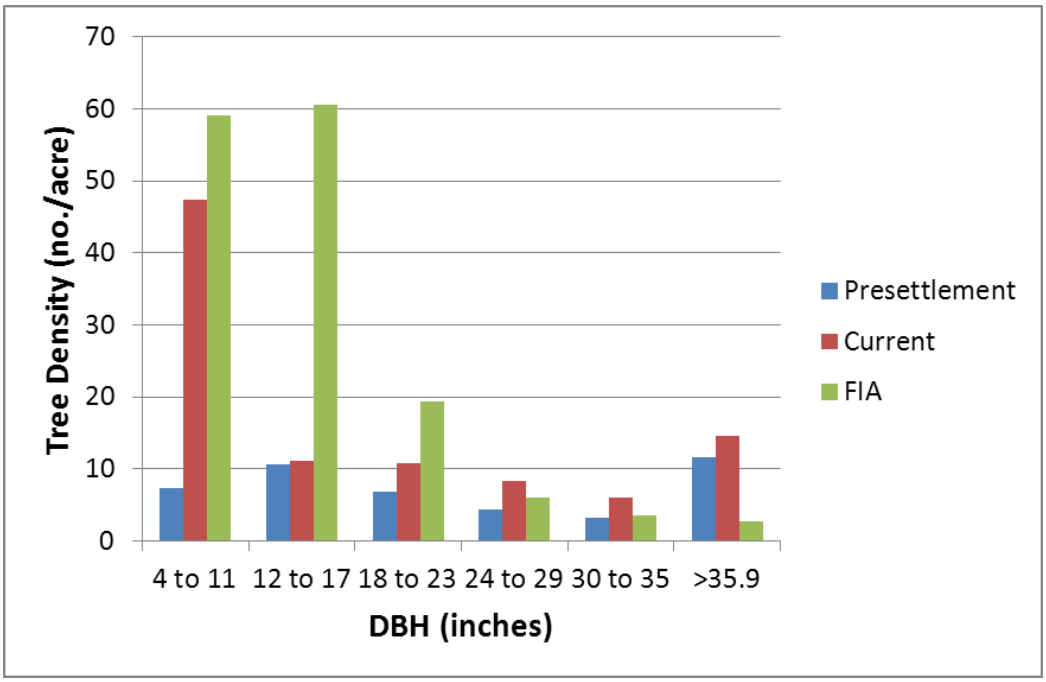


Figure 5. Mean (± SD) density by tree species for estimated presettlement (1860) and current re-inventory (2013) mixed conifer stands. Species are abbreviated as follows: JP=Jeffrey pine, SP=sugar pine, WF=white fir, RF=red fir, and IC=incense cedar.

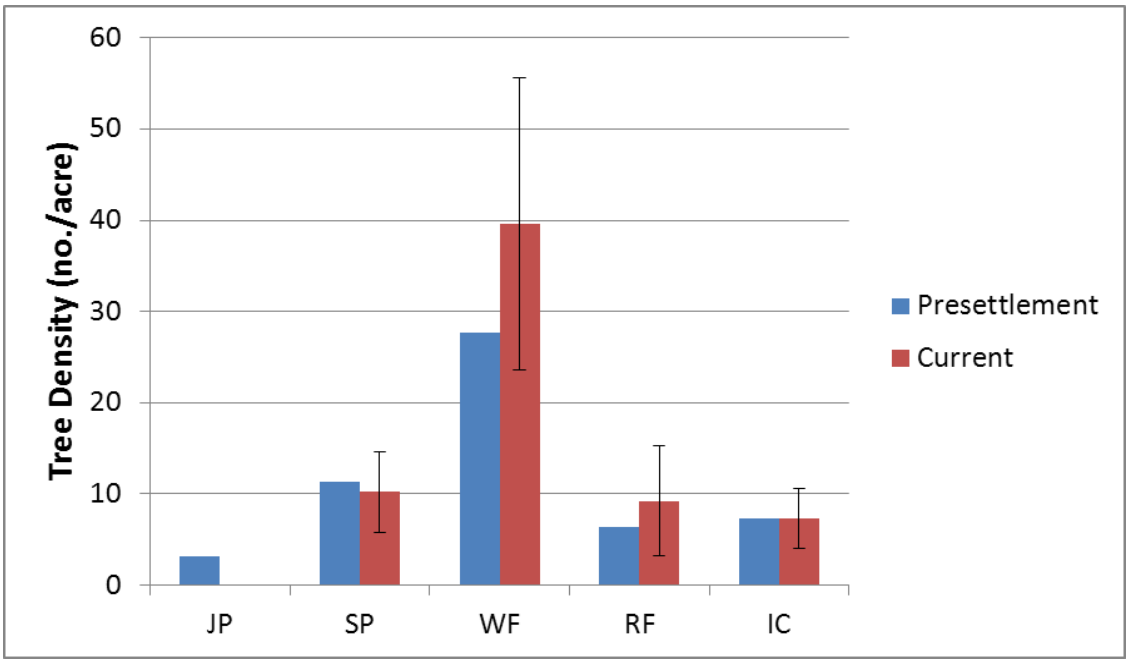


Figure 6. Mean (± SD) dominant tree (≥24 inches dbh) density by species for historic (1929) and current re-inventory (2013) mixed conifer stands. See Figure 5 for species abbreviations.

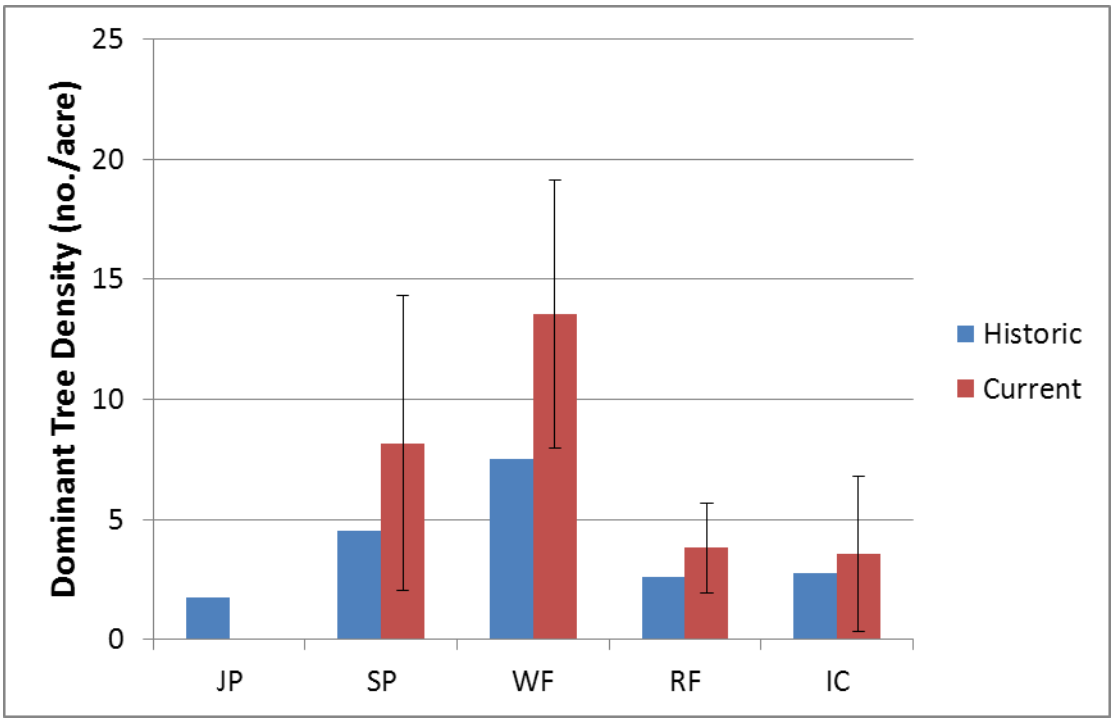


Figure 7. Mean (± SD) dbh of all trees within presettlement (1860) and current re-inventory (2013) mixed conifer stands.

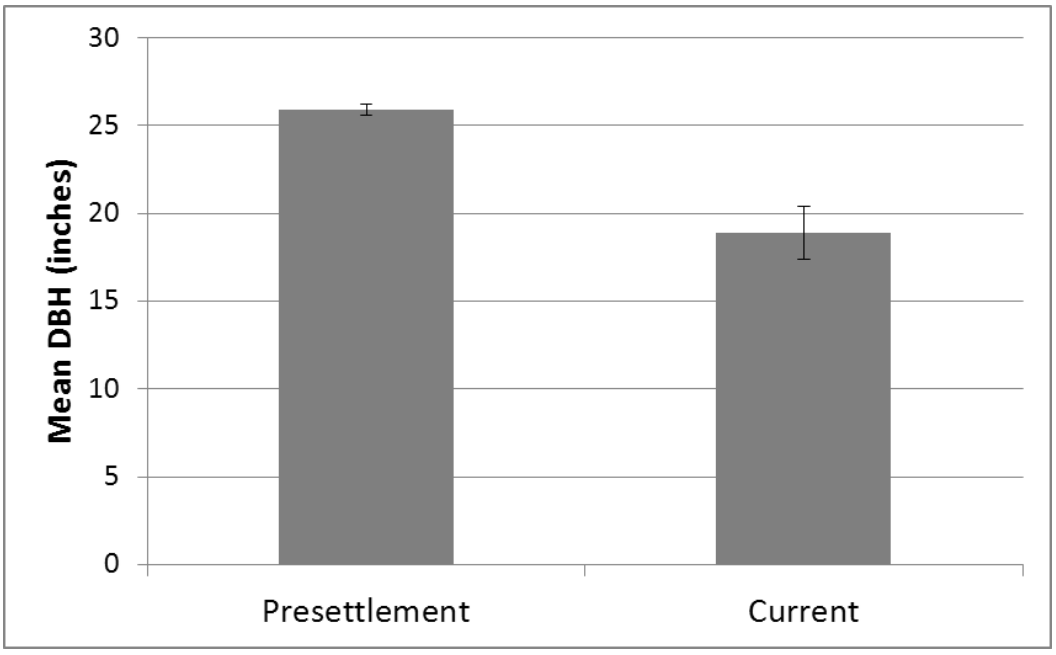


Figure 8. Mean (± SD) canopy cover in historic (1929 and earlier) and current (2013) mixed conifer stands. Estimates are based on historic Methods of Cutting plots (Historic-MOC; FVS-modeled estimates), historic and presettlement Natural Range of Variation assessment (Historic-NRV; Safford 2013), current re-inventory from FVS-modeling (Current-FVS), field ocular estimates (Current-Field), and FIA data (2013) for the Southern Sierra.

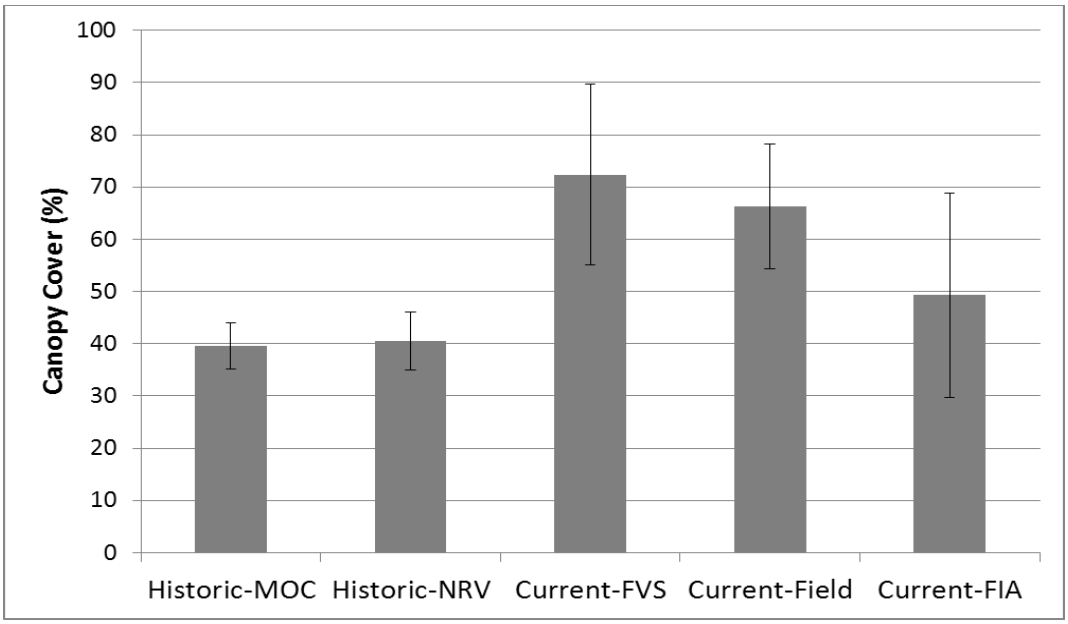


Figure 9. Mean (± SD) snag density (≥4 inches dbh) for historic (1929), current re-inventory (2013), and current FIA (2013) mixed conifer stands.

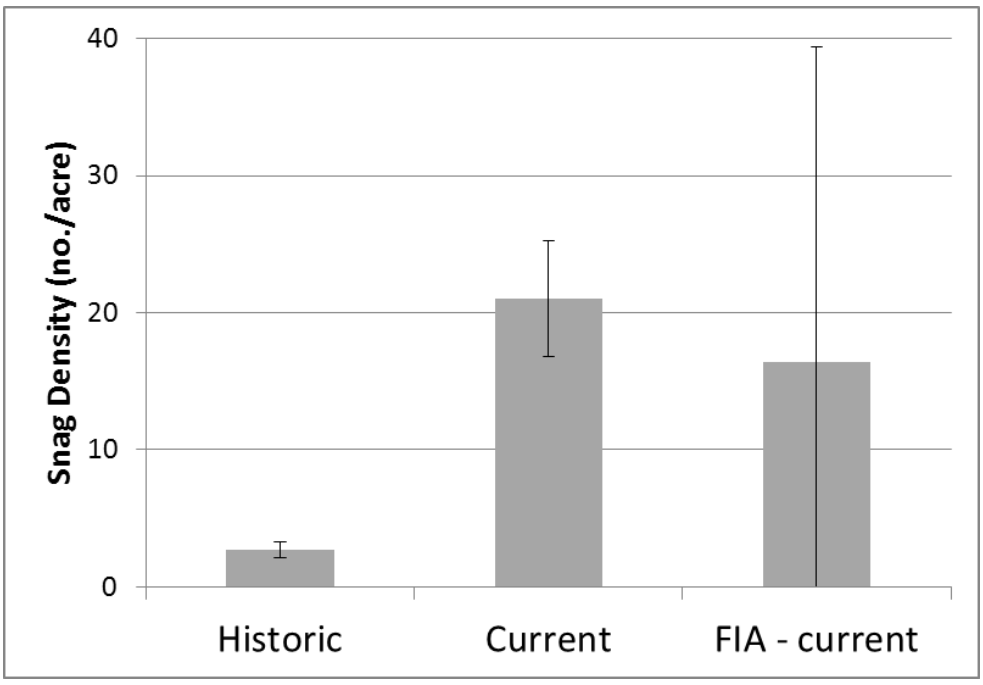


Figure 10. Mean (± SD) tree regeneration (seedlings and saplings) by species for historic (1929), current re-inventory (2013), and current FIA (2013) mixed conifer stands. Standard deviation for FIA-Current (±1674) and not drawn to scale.

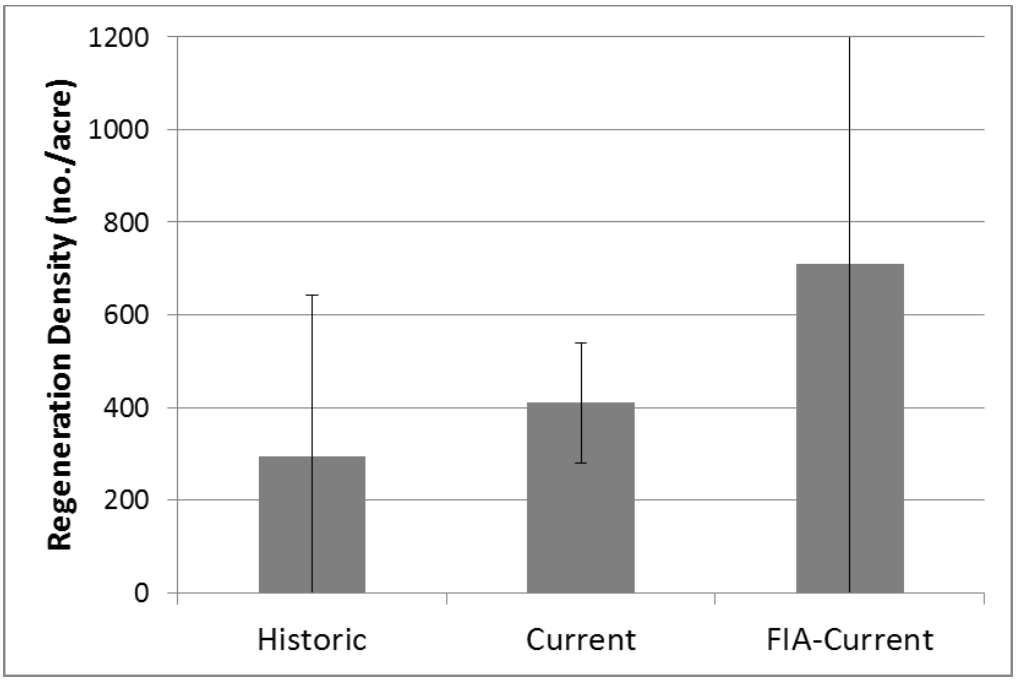


Figure 11. Mean (± SD) tree regeneration density by species for historic (1929) and current re-inventory (2013) mixed conifer stands.

Figure 12. Mean (± SD) shrub cover for historic (1929), current re-inventory (2013), and current FIA (2013) mixed conifer stands.

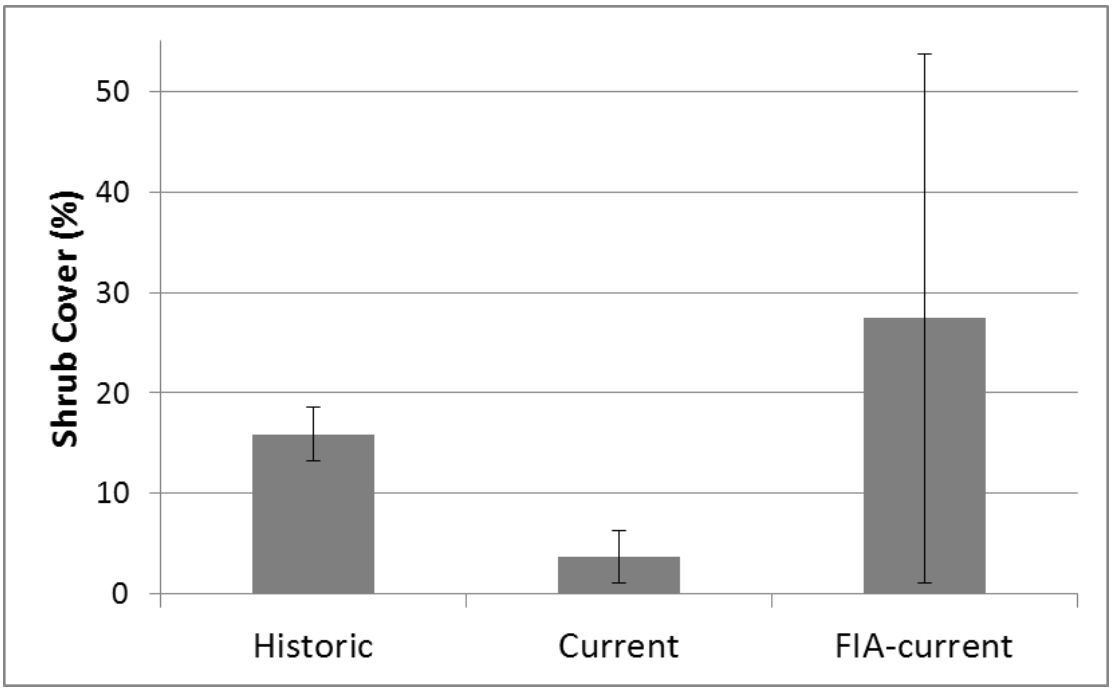


Figure 13. Mean (± SD) tree density for presettlement (1860) and current FIA (2013) ponderosa pine stands. Historic data in this and following figures is represented by a single 10-acre stand. FIA data in this and following figures for ponderosa pine forest is based on a summary of 136 plots exclusively from the southern Sierra Nevada.

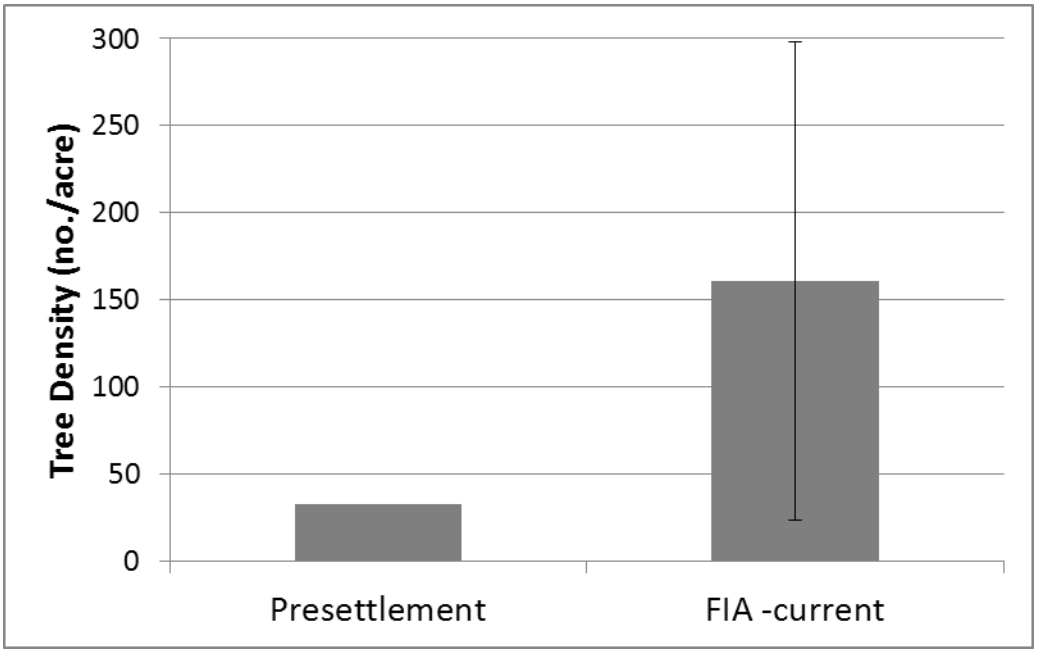


Figure 14. Mean (± SD) basal area for presettlement (1860) and current FIA (2013) ponderosa pine stands.

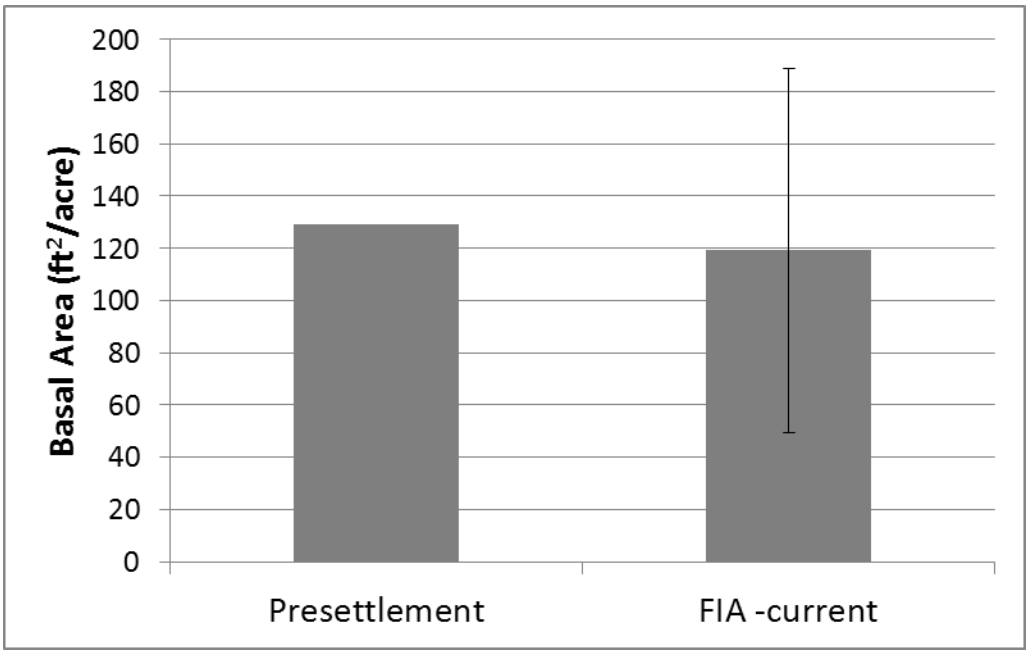


Figure 15. Mean (± SD) canopy cover for historic (1911), historic Natural Range of Variation (NRV; Safford 2013), and current FIA (2013) ponderosa pine stands. Historic NRV estimate includes ponderosa and Jeffrey pine stands.

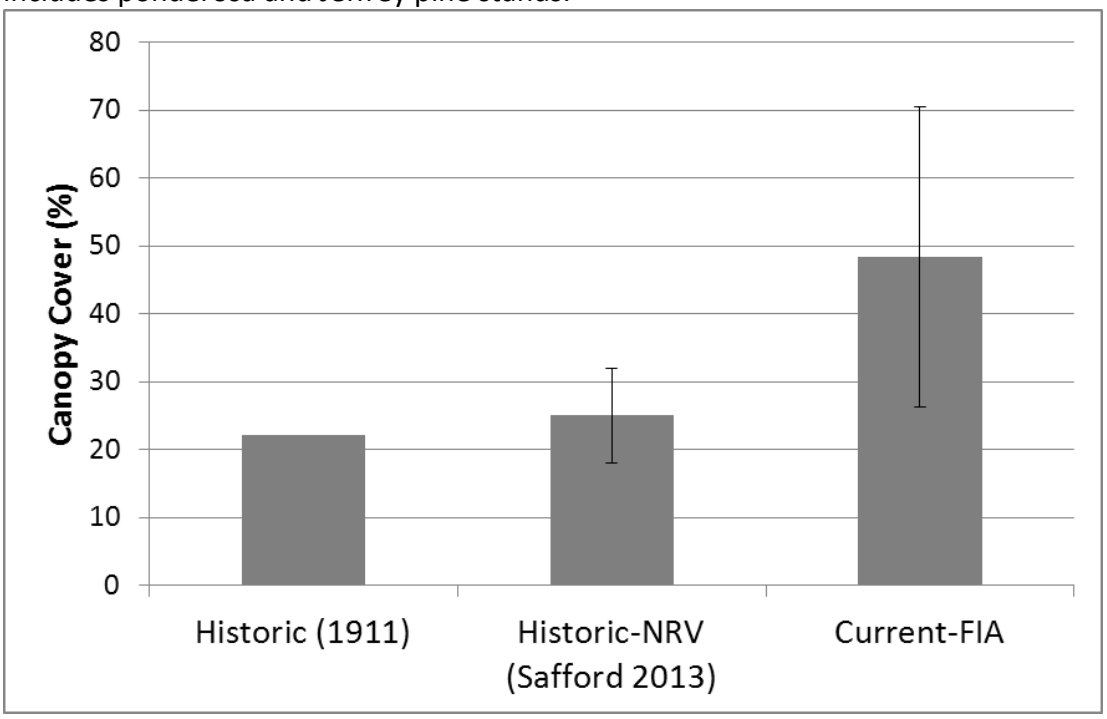
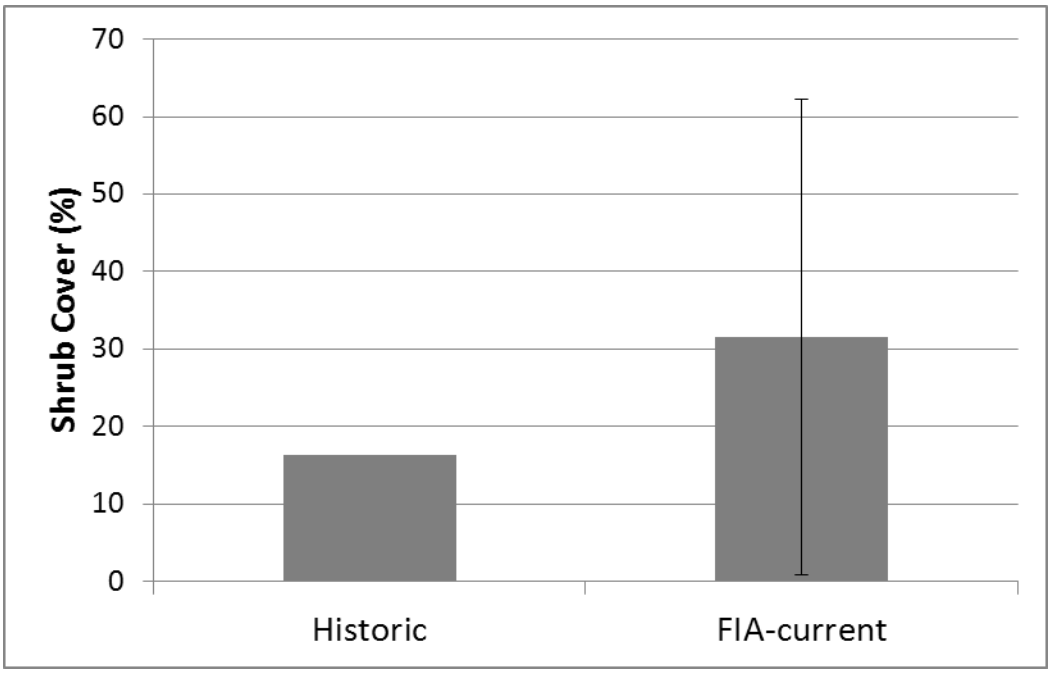


Figure 16. Mean (± SD) shrub cover for historic (1911) and current FIA (2013) ponderosa pine stands.



Appendix A.

Figures 17 a-d. Size class distribution by species of historic (1929) and current re-inventory (2013) mixed conifer stands numbers 2 (Figs. 17a and 17b) and 3 (Figs. 17c and 17d). Presettlement (1860) and historic (1929) values are identical, with the exception that the presettlement 4 to 11 inch dbh class is estimated as an average of all other (larger) size classes, typical of presettlement mixed conifer stands in the Sierra Nevada (Safford 2013). See Fig. 5 for species abbreviations.

Figure 17a

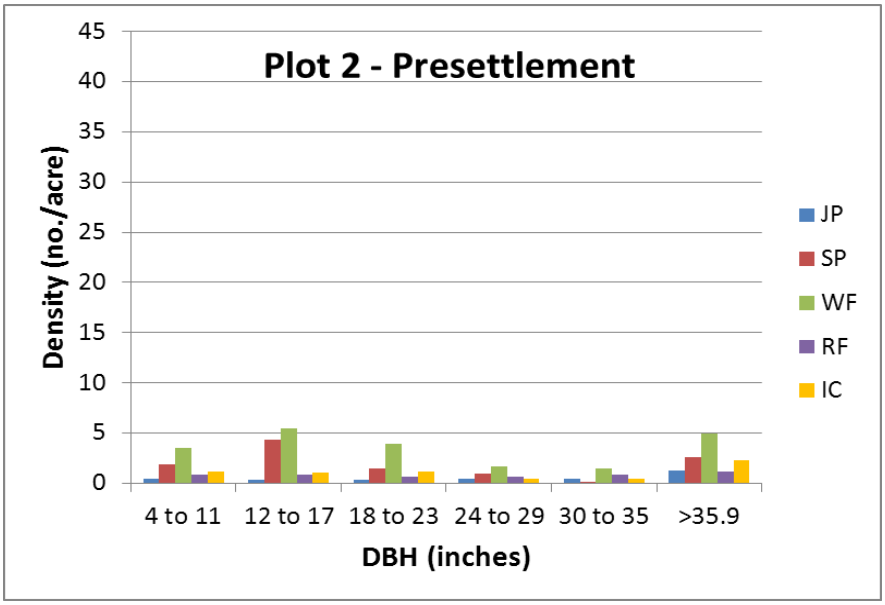


Figure 17b.

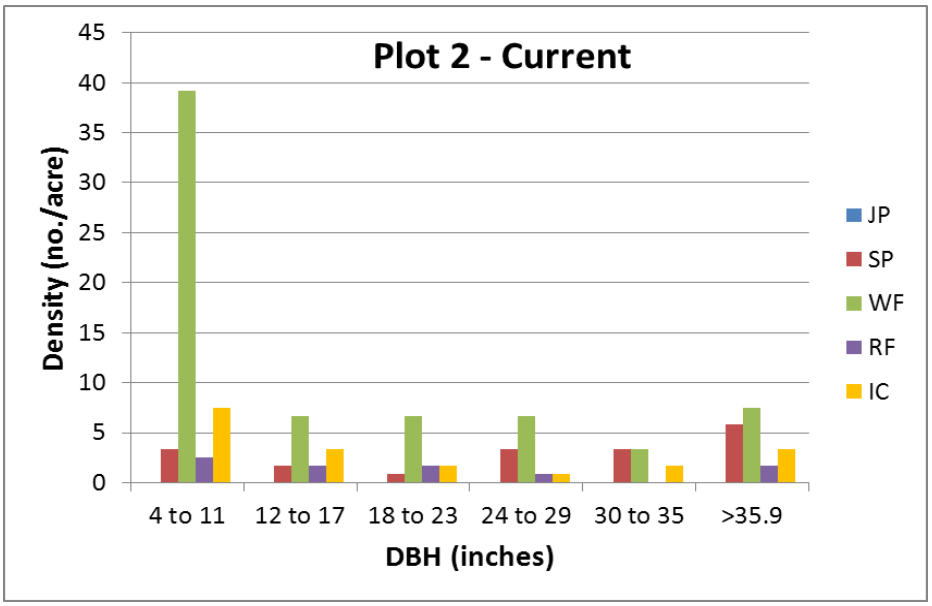


Figure 17c.

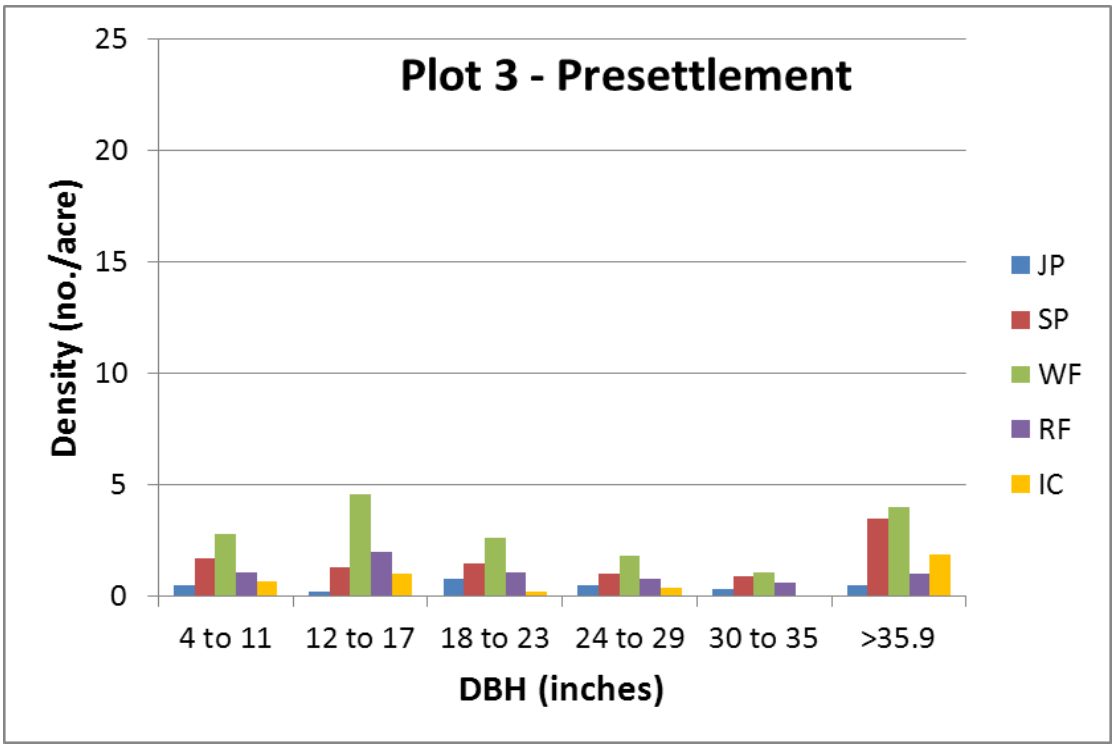
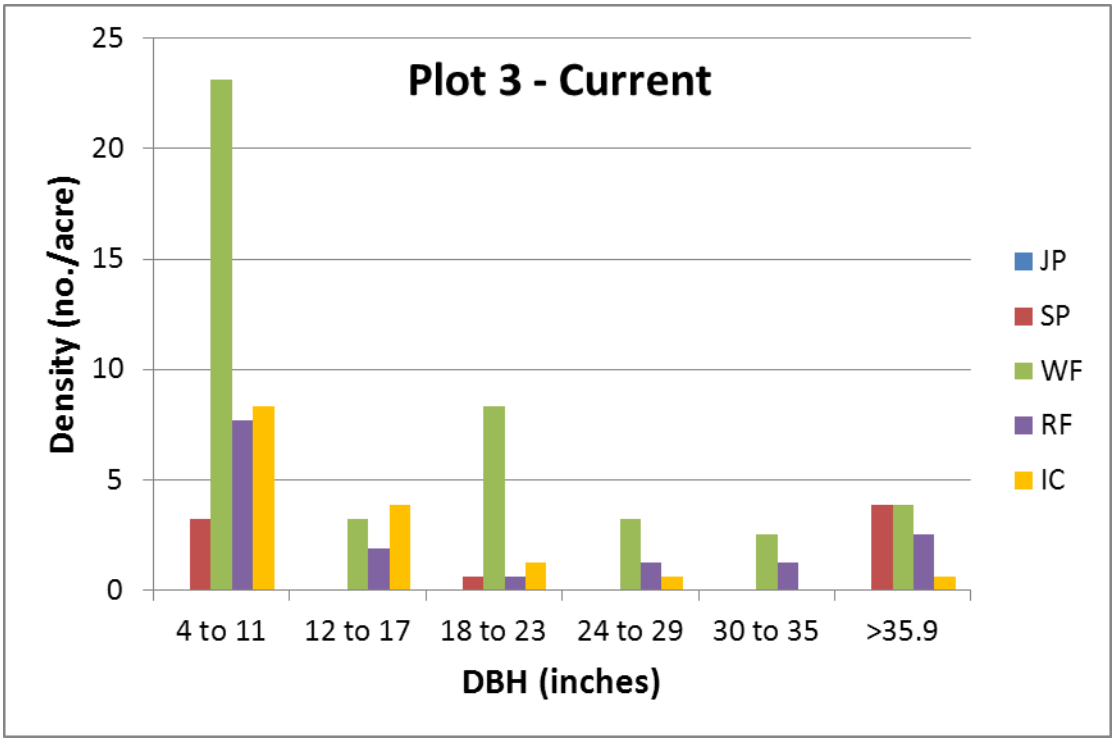


Figure 17d.



Figures 18a-b. Size class distribution by species of presettlement (1860) and historic (1911) ponderosa pine stands (MOC plot 1). Presettlement (1860) and historic (1929) values are identical, with the exception that the presettlement 4 to 11 inch dbh class is estimated as an average of all other (larger) size classes, typical of presettlement yellow pine stands in the Sierra Nevada (Safford 2013). Current data are unavailable (see Background section). Species are abbreviated as follows: PP = ponderosa pine, SP = sugar pine, WF = white fir, and IC = incense cedar.

Figure 18a.

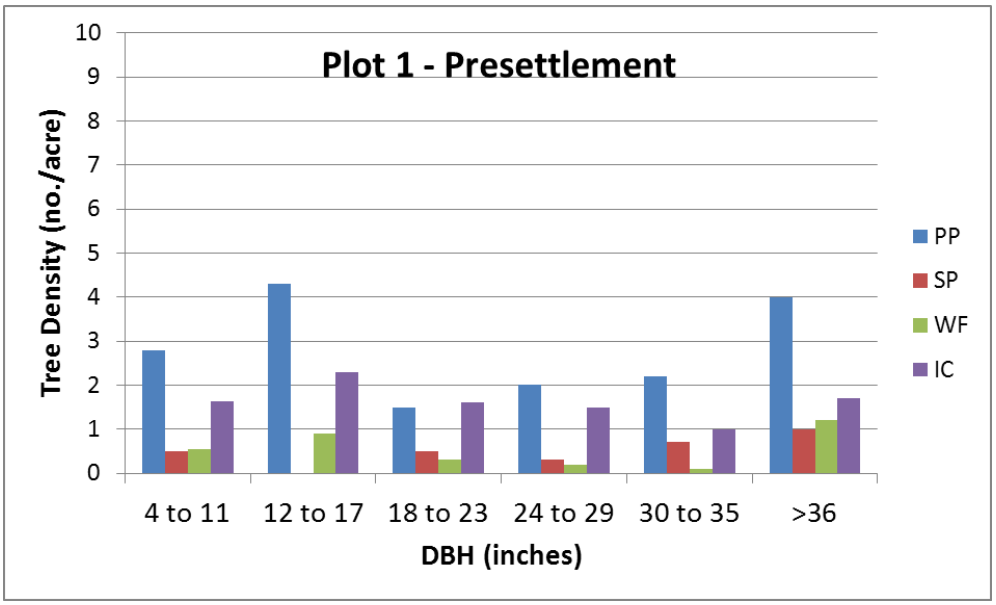


Figure 18b.

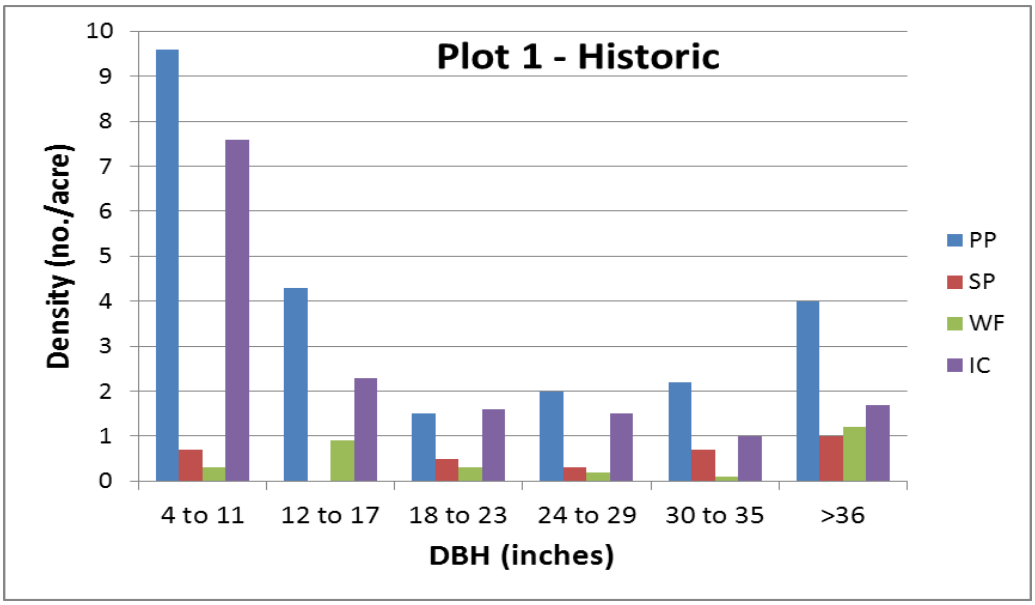
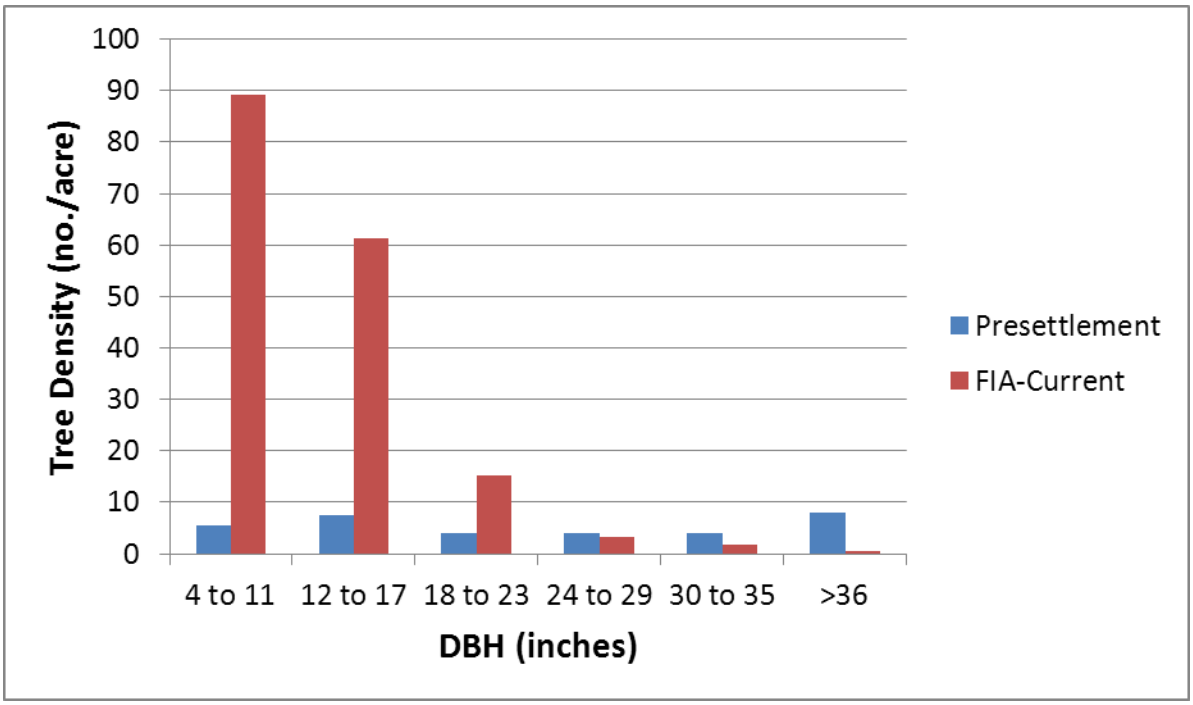


Figure 19. Size class distribution of the presettlement (1860) ponderosa pine stand (MOC plot 1) compared with current FIA plots in yellow pine stands of the southern Sierra Nevada.



Appendix B. Historic and current “Methods of Cutting” photo comparisons for mixed conifer plots (plots 2 and 3). Current photos were taken in 2013.

Figure 20. Historic (top) and current (bottom) mixed conifer plot no. 2 looking northwest from tree no. 34. Note the variation in stand conditions between the foreground and background in the top photo.

Figure 21. Historic (top) and current (bottom) mixed conifer plot no. 2 looking northeast from tree no. 34.

Figure 22. Historic (top) and current (bottom) mixed conifer plot no. 2 looking northwest from tree no. 678 (top) and west from tree 678 (bottom).

Figure 23. Historic (top) and current (bottom) mixed conifer plot no. 2 looking northwest from tree no. 64.